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THE ALGÆ OF KANSAS RESERVOIRS.

(PRELIMINARY PAPER.)

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THIS investigation was undertaken with a twofold purpose. First, it is intended that the data when available in completed form shall serve as an aid to the sanitary engineer by explaining the harmful effects of heavy growths of microorganisms in the city water reservoirs, and by describing the organisms causing trouble and the best methods for their eradication. Second, it is the first survey of the algæ of Kansas by the University. This survey was planned several years ago by the department of botany and the Water Survey, but was not begun until the summer of 1915, when the author made his first complete survey of the reservoirs of the surface water supplies in Kansas.

The study of the microörganisms in water has gone hand in hand with the development of the compound microscope, dating back to the seventeenth century. In 1850 Doctor Hassall, of London, first called attention to the fact that these organisms have a sanitary significance in drinking water. In 1887 the first systematic examination of the water supplies in this country was made by the Massachusetts State Board of Health. Since that time survey work upon the algæ of the water supplies has been done in many states preliminary to the practical work of the sanitary engineer.

The first data upon the algæ found in Kansas was published in September, 1884, in a bulletin of the Washburn laboratory of natural history. This was a list of twelve species, identified by the Rev. Francis Wolle, of Bethlehem, Pa., and was incorporated in the Biological Survey which Francis W. Cragin, professor of natural history, was conducting at Washburn College. In January, 1885, July, 1886, and January, 1889, the second, third and last lists appeared. Altogether there were listed fifty-three species. These publications contain all of the data which is available in our state upon our local algæ.

In our neighboring states considerable work on the listing of the algæ has been published. Nebraska has issued, through its Botanical Survey, five bulletins under the directions of Professors Bessey, Pound, Clements and Webber. In Iowa,

R. E. Buchanan published "Notes of the Algæ of Iowa." Colorado has two reports by G. H. Wailes and W. W. Robbins. Missouri has a survey bulletin prepared by Miss Ada Hayden on the "Algæ Flora of the Missouri Botanical Garden of St. Louis" and a "Preliminary Check List," prepared by the Englemann Botanical Club, containing about one hundred and thirty-five species. Oklahoma has published no lists of their algæ flora.

The work of G. N. Calkins and G. C. Whipple and others have shown the marked effect that heavy growths of certain genera of algæ have upon the usability of drinking water. In the first place, the water often is given a very disagreeable odor. These odors can be classified into natural odors and those of decomposition. The former are often described as aromatic odors, especially for those of the Diatomaceæ, grassy odors for the Myxophyceæ, and fishy odors for the Chlorophyceæ. The odors of decomposition are usually more offensive than the natural odors. The Myxophyceæ, when decaying, give a "pig-pen" odor, *Beggiatoa* gives the odor of hydrogen sulphide or "rotten eggs," while to some of the other genera the odor of garlic, onions, etc., is ascribed. Water having these strong odors also has a very disagreeable taste. The decaying vegetation often gives the water in addition a yellowish-brown color, making it unattractive and in some cases unfit for use, even for washing purposes. Besides this trouble with odors, tastes and color, the algal forms do much damage in clogging the filters and decreasing the length of run quite materially. The diatoms and other unicellular forms cause the most trouble because of the dense mat which they are able to form over the top of the sand. The filamentous algæ, which grow erect upon the sand, do not thus clog the filter, but, on the contrary, they prevent clogging to some extent by their waving threads. However, when these forms decay they too settle to the bottom and block the filter. Another danger to the filter is due to the release of gas by these plant forms, which at times is sufficient to cause great masses of the mat to rise, thus exposing the sand so that the water filters through it much more rapidly than it should to give efficient results in the tap water.

The elimination of the algæ from the filters can be accomplished by covering them, since these plants can live only in the light. The eradication of the algæ from the reservoirs was a problem until Moore and Kellerman, in 1905, issued a report stating their successful experiments in the removal of algæ by the use of copper sulphate. This treatment has been in practice ever since, and has proven to be entirely satisfactory. The method of application as given by the above-mentioned workers is as follows: "Place the required number of pounds of copper sulphate in a coarse bag, gunny sack or some equally loose mesh, and attaching this to the stern of a rowboat near the surface of the water, row slowly back and forth over the reservoir, on each trip keeping the boat within ten to twenty feet of the previous path. In this manner about one hundred pounds of copper sulphate can be distributed in one hour." Care should always be exercised in dosing not to allow too great a concentration of the solution to be made in one place, because of the danger to fish swimming through that portion. The writer found that it is always better to make the treatment on a windy day, so that the currents in the water may more readily distribute the chemical.

It is of great importance to determine the exact proportion of copper sulphate to the volume of water to be dosed, since too small a proportion will not affect the algæ and too great involves unnecessary expense, and may kill off the fish. The quantity of water to be treated in a large impounding reservoir may be estimated by multiplying the number of acres of water surface by the average depth (taken as about $\frac{1}{3}$ of the maximum depth) and dividing this product by 3. This gives approximately the number of million gallons of water in the reservoir.

Since some genera of algæ require more copper sulphate than others, it is quite essential that the genus of the algæ causing the trouble be determined by microscopical examination. The algæ which appeared in the reservoirs in the two years' survey, and which, therefore, are the most common in Kansas, may be identified by the descriptions in the key and drawings included in the final report.

After the quantity of water to be treated and the causative organisms have been determined, the dosage of $CuSO_4$ may be found by referring to Table II in the final report, a portion of which is given below.

Quantity of Copper Sulphate required to kill various forms of odor-producing organisms.

Expressed in pounds per million gallons of water.

Anabæna	0.75	Draparnaldia	2.5
Asterionella	0.80	Euglena	8.3
Cladophora	8.30	Fragilaria	2.1
Clathrocystis	0.8	Navicula	0.6
Conferva	3.3 to 16.0	Oscillatoria	0.8 to 3.3
Chlamydomonas	4.2	Spirogyra	0.4 to 2.5
Dinobryon	2.5	Ulothrix	1.7

Immediately following the killing off of the algæ by $CuSO_4$ the odor often increases for a few days because of disintegration, but this soon passes away. Another effect of the disintegration of the algæ is the perceptible increase in the bacterial count. This can be kept down by the proper use of hypochlorite.

Aëration also has a marked effect in the decrease of the algæ, by liberating the carbon dioxide gas which is essential to these plants for the manufacture of their food. Then, too, the odors of the algæ are liberated by this treatment. Many of the superintendents of the southern part of Kansas use the aërating system to free the water of the sulphur odor. A few workers have reported a ready removal of certain kinds of algæ from drinking water by direct oxidation with ozone, but from a practical point of view this method has never been developed.

We have in Kansas forty-three surface water supplies whose water is analyzed at the water and sewage laboratory of the State Board of Health at Lawrence once a week. This made it an easy matter for the writter to obtain samples of "moss" and algæ from the reservoirs at any time. Collections were made in the summer and winter of 1915 and the spring, summer and winter of 1916. This checking of each reservoir five times should bring out any changes due to differences in the seasons and give a more complete record on the flora of each reservoir.

The bottles used in collecting the algæ were large-mouthed, glass-stoppered, 100 cc. bottles, usually filled about one-half full of a 2 percent solution of formaline. Most of the analyses were made from preserved material. However, one complete analysis was made from each town on the living material, which was shipped into the laboratory on ice, and allowed to grow in aquaria.

In most cases the algæ were present in sufficient quantities to examine direct from the samples. In those cases in which small masses of the algæ could not be found in the basin or reservoir a liter of water from the basin was taken and the microörganisms present concentrated by the Sedgwick-Rafter filter method. This method of determining the actual number of microörganisms per cubic centimeter of water is especially valuable in recording the reduction of organisms during the copper-sulphate treatment. Most of the species found by this method were diatoms and other unicellular algæ.

At times samples of living algæ came into the laboratory in a vegetative condition and the species could not be accurately determined without the fruiting stage. This was especially true of the Conjugatæ. For such forms Klebs' method was used to induce fruiting. According to this method, such forms as *Spirogyra,* in a vegetative state, were placed in an aquarium of about 2 percent Knop's solution and left to grow for a few days. When a vigorous growth was shown the algæ were transplanted to a jar of distilled water in the sunlight. In most cases these conditions caused conjugation, aiding greatly in classification to species.

The key before mentioned contains an accurate and concise description of the 110 species of algæ found throughout the five seasons covered by this survey, and a brief statement concerning the locality of each. There are thirty-eight figures in this report, drawn by the aid of the camera lucida from the material examined, which will greatly aid the student of microscopy in his identification and classification work.

Below are listed the genera of the algæ found throughout this survey, and the number of times each was found:

Myxophyceæ:	
Anabaena	4
Clathrocystis	8
Glęocapsa	1
Hypheothrix	1
Lyngbya	42
Merismopedium	6
Microcoleus	2
Nostoc	2
Oscillatoria	91
Phormidium	2
Spirulina	8
Total	167
Flagellata:	
Dinobryon	1
Euglena	5
Total	6
Heterokontæ:	
Conferva	15
Ophiocytium	2
Total	17
Chlorophyceæ:	
Botryococcus	1
Characium	2
Chalamydomonas	8

Chlorophyceæ:	
Cladophora	7
Closterium	4
Coelastrum	3
Cosmarium	11
Dictyosphaerium	5
Draparnaldia	1
Microspora	4
Microthamium	1
Mougeotia	6
Oedogonium	6
Pandorina	8
Pediastrum	5
Raphidium	17
Scenedesmus	10
Spirogyra	7
Stigeoclonium	3
Tetraspora	3
Haematococcus	1
Ulothrix	1
Zygnema	1
Total	115

Bacillarieæ:	
Amphora	10
Cymbella	23
Cocconeis	1
Encyonema	1
Fragillaria	4
Gomphonema	7
Melosira	3
Navicula	85
Nitzschia	8
Pleurosigma	11
Stauroneis	1
Surirella	3
Synedra	25
Total	182
Grand total	486

Out of the many cases handled by the workers in the water laboratory several interesting ones, showing the value of the copper method of removing algæ from the reservoirs in Kansas, will be briefly mentioned below.

In June, 1916, the water at Horton, Kan., was in "bad" condition, according to Superintendent W. W. Wood. The author made a trip to Horton and found the water had a very disagreeable odor and a dark reddish-brown color. The reservoir was found to be covered with a decaying mat of *Cladophora, Spirogyra, Zygnema, Mougeotia, Anabæna, Closterium, Euglena* and *Characium.* The odor from the reservoir was due to these decaying forms, likewise the color. The settling basin showed a count of sixty-eight organisms per cubic centimeter of water, forty-nine of which were *Anabæna.* The basin, with a capacity of 600,000 gallons of water, was treated with two and one-half pounds of $CuSO_4$ and allowed to stand for twenty-four hours. The supply was changed from the infested reservoir to the creek, whose overflow supplies the reservoir and whose waters at that time were comparatively free from algæ. In forty-eight hours all odors and color had disappeared.

In the fall of 1916 the Olathe water system was infested with extremely heavy growths of *Conferva.* Much of the dense entaglement was raked out upon the banks and the waters were treated at the rate of six pounds of $CuSO_4$ to a million gallons of water. The water was usable within three days.

Russell, whose impounding reservoir has a capacity of 39,000,000 gallons, was greatly troubled in September, 1916, with heavy growths of *Anabæna, Coferva* and *Cladophora.* The lowering waters had left a carpet of decaying algæ about the edge. The reservoir was treated with 50 pounds of the copper salt, and 100 more pounds were sprayed about the banks. No further trouble was reported.

In March, 1917, Burlington reported a very "bad taste" to the city water, and extremely offensive odors rising especially from the filter beds. Analyses showed the filters to be covered with numerous *Synedra, Navicula, Chlamydomonas* and *Clathrocystis.* The filters were washed, and about a foot of water, to which one pound of $CuSO_4$ had been added, was left standing in each. The basins were treated with eight pounds to the million gallons. The filters, after standing for eight hours, were drained into the sewer, and the water now let in from the basin and filtered was in good condition.

Occasionally difficulty which seems to be due to the algæ may be caused by the growth of small animals. A few cases in our state where water from the basins and filters has given off very foul odors have been traced to this cause. Early in May, 1917, Lyndon reported a very offensive fishy odor coming from their settling basin and filter. The walls were covered with a brownish-gray growth much resembling masses of roots. A sample of this material analyzed in the laboratory proved to be a *Polyozoa,* minute animals forming mosslike clusters. These small animals when in a state of decomposition give off an odor much the same as comes from a stagnant fish pond. The treatment advised was purely a mechanical one. The walls were scraped and the filters carefully cleaned. This seemed quickly to remove all the difficulty as to odors. In January, 1917, Kansas City complained of the heavy growths and bad fishy odors in their basins. The infesting form was found to be a *Polyozoan.* In February, 1917, great quantities of *Vorticella* were found to be the chief trouble causers at the State Hospital at Osawatomie. This small protozoan was successfully eradicated with copper sulfate.

SUMMARY.

Although there were but 13 genera of diatoms classified, they appeared 182 times, while the 23 genera of Chlorophyceæ, of which there were 55 species, were found only 114 times.

Thirty-six species of Myxophyceæ, falling under 11 genera, were found 167 times. There were 4 species of Heterokontæ and 2 Flagellata. The grand total indicates that the 51 genera of algæ appeared 486 times throughout the survey. Fourteen species of *Oscillatoria* were classified. This genus was found 91 times, and is the most common algal form prevalent in our reservoirs. The diatoms were always present, *Navicula* being found 85 times. It is of interest to note that although the specific genera varied from season to season, the number of genera remained quite constant.

The algæ of our state which have been found to be the most active in causing bad tastes, odors or colors in our drinking water are *Anabæna, Confervæ, Oscillatoria, Spirogyra, Cladophora, Clathrocystis, Synedra* and *Navicula.* Animals of the *Polyozoan* and *Protozoan* groups have also been found to cause these difficulties.

The collections of algæ during the five seasons brought out no changes due to the differences in the seasons. To determine whether this is due to the absence of seasonal influence on the flora or to the artificial conditions of the reservoirs requres data from a longer period of time than is covered by this paper.

The copper sulphate treatment for algal trouble has been very successful in Kansas.

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